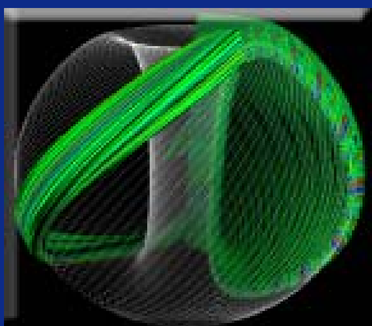
Fusion Energy Sciences

Office of Science

U.S. Department of Energy

The Office of Science's Fusion Energy Sciences (FES) program supports advances in plasma science, fusion science, and fusion technology--the knowledge base needed for an economically and environmentally attractive fusion energy source. FES is pursuing this goal through an integrated program of research based in U.S. universities, industry, and national laboratories, augmented by a broad program of international collaboration.

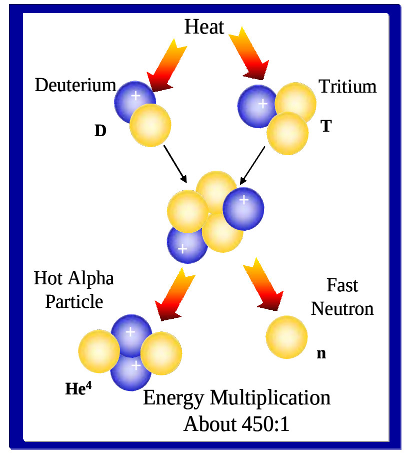


Advanced Scientific Computing in Fusion Energy Science

C-Mod Plasma

The Opportunity

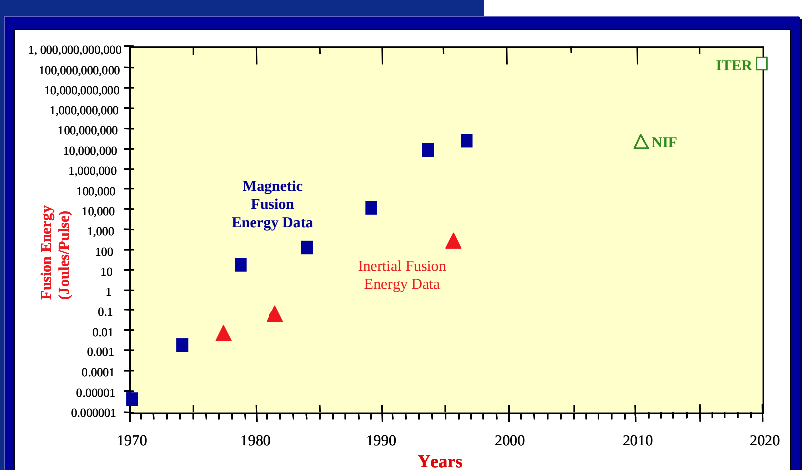
Fusion is the power source of the sun and the stars. It occurs when forms of the lightest atom, hydrogen, combine to make helium in a very hot (100 million degrees centigrade) highly charged gas, or plasma. A small amount of matter involved in the reaction is converted to a large amount of energy. When developed, fusion will provide a virtually inexhaustible, safe, environmentally benign, and affordable energy source. Fusion's fundamental fuel, deuterium and tritium, is readily available from sources as common as seawater and lithium in the earth's crust, and thus would be accessible and abundant to all nations.



Fusion Reaction

The Challenge

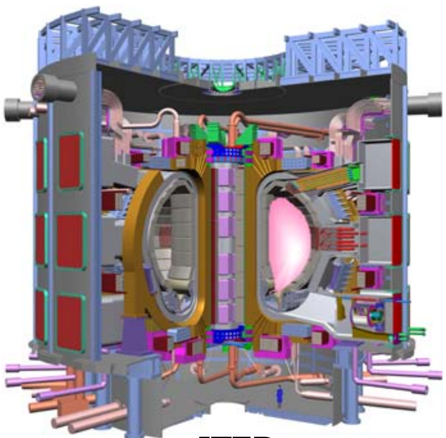
Researchers supported by the FES program now have high confidence that it will be possible to design and build a fusion power plant. The major scientific challenge today is to make fusion energy practical by advancing the predictive capability based on detailed experimental campaigns, sophisticated modeling, and high-end computing. Already, dramatic advances in the scientific understanding of fusion plasmas have been achieved using the Department of Energy's (DOE) advanced computing capability. And with newly improved instrumentation, there is now a more refined measurement of the interior of these complex hot plasmas. The net result is an improvement in the ability to design and build the machines of the future. Enhanced scientific diagnostic and computational capabilities will continue to be key to further advances.



Progress in Fusion Energy Production

There are <u>two distinct approaches</u> to producing fusion energy: Magnetic Fusion Energy (MFE) and Inertial Fusion Energy (IFE). MFE uses a magnetic field to confine a plasma and hold it at the required density and temperature. The fusion energy produced in individual magnetic confinement fusion experiments has risen by a factor of more than one trillion since 1970 (see graph), while computer speed has risen by a factor of 100,000. Progress in fusion energy has produced much deeper understanding of the underlying plasma science.

To date, MFE has been the primary subject of research worldwide for fusion energy applications. Consequently, the U.S. fusion program is highly leveraged with more than $1 billion in magnetic fusion research performed by other nations. Magnetic fusion research is an international effort in which experimental results are openly shared and in which collaboration on experiments is extensive.



ITER

The next major frontier for this program is understanding the physics of a "burning" plasma—a plasma in which the burn up of the fusion fuel contributes significantly to the heat necessary to sustain the fusion reaction—of the type necessary for a fusion power plant. The ability to extend fusion to practical energy applications is critically dependent on this understanding, which requires a fusion facility for sustained burning plasma research — with an emphasis on ITER (which in Latin means "the way"). Since June 2003, the U.S., China, the European Union, Japan, South Korea, and the Russian Federation have conducted high-level negotiations on numerous scientific and international ITER project-oriented issues, but none more important than the selection of the project site. The current candidate host sites have been narrowed to Cadarache, France (EU) and Rokkasho, Japan. Both sites have been found to be excellent candidate sites for ITER. Considering the recent bilateral negotiations and revised proposals by the European Union and Japan, a site selection decision could occur in early 2005.

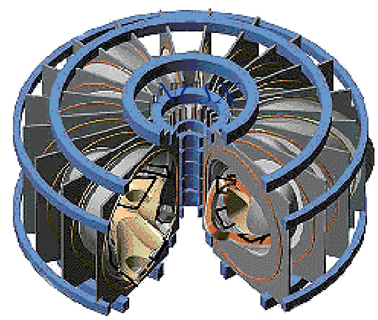
For IFE, powerful lasers or particle beams are focused on a small pellet of fuel for a few billionths of a second. Research on the transformation of these small pellets to plasmas of very high energy density important to IFE, has been pursued primarily as a key component of the DOE's Stockpile Stewardship Program. Leveraging this large investment is an excellent opportunity because IFE may also present a promising path to practical fusion power. Current IFE related research efforts in the Office of Science are focused on leading edge high energy density physics.

Investment Plan

The FES research plan focuses on the following areas:

- Advanced understanding and innovation in high performance plasmas on major facilities and participation in a burning plasma physics experiment
- Basic plasma science and computational programs
- Innovative experiments to broaden the science base and perhaps make fusion more practical
- Research on high energy density physics relevant to fusion energy sciences
- A fusion technology program in support of fusion science experiments and the longer term needs of fusion energy.

Construction of an innovative new experimental facility, the National Compact Stellarator Experiment (NCSX), is underway at the Princeton Plasma Physics Laboratory. It is the product of several years of advanced 3-D computer modeling and offers potential improvements over the more extensively researched tokamak concept.



The Benefits

A science-based approach to fusion offers the fastest path to commercial fusion energy and is advancing our knowledge of plasma physics and associated technologies, yielding near-term benefits in a broad range of scientific disciplines. Examples include plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative material coatings, the efficient destruction of chemical and radioactive wastes, and more efficient space propulsion.

Contact

Dr. Anne Davies, Associate Director for Fusion Energy Sciences
Office of Science
U.S. Department of Energy, Headquarters
1000 Independance Ave. SW
Washington, DC 20585-1290
Phone: 301-903-4941 Fax: 301-903-8584
E-mail: Anne.Davies@science.doe.gov
Website: www.ofes.science.doe.gov
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